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(54) **METHODS AND SYSTEMS FOR REPRESENTING, USING AND DISPLAYING TIME-VARYING INFORMATION ON THE SEMANTIC WEB**

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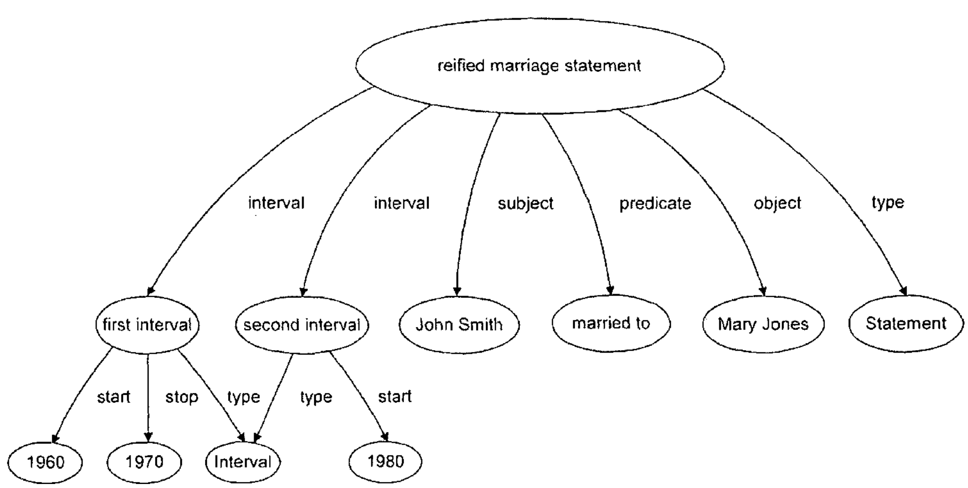
(57) **ABSTRACT**

Methods and systems for providing start and stop properties to Semantic Web structured resources and statements are disclosed. The start and stop properties can specify a lifetime during which a resource or statement can be valid. A call or query to one or more resources can return statement data including the start and stop properties for the resources and/or statements. Dates can be specified with the call or query such that the returned resources and statements have lifetimes including the specified dates. Screen images of the data can display subject and object nodes and predicate arcs for the selected dates. A sequence of screen images can display a timeline of nodes and arcs by adding or hiding nodes and arcs to correspond with the start and stop properties of the statements. Tools are provided for the user to navigate through the sequence.

22 Claims, 16 Drawing Sheets



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14. ABSTRACT
Methods and systems for providing start and stop properties to Semantic Web structured resources and statements are disclosed. The start and stop properties can specify a lifetime during which a resource or statement can be valid. A call or query to one or more resources can return statement data including the start and stop properties for the resources and/or statements. Dates can be specified with the call or query such that the returned resources and statements have lifetimes including the specified dates. Screen images of the data can display subject and object nodes and predicate arcs for the selected dates. A sequence of screen images can display a timeline of nodes and arcs by adding or hiding nodes and arcs to correspond with the start and stop properties of the statements. Tools are provided for the user to navigate through the sequence.

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Office Action issued in U.S. Appl. No. 11/411,206 on Aug. 13, 2009.
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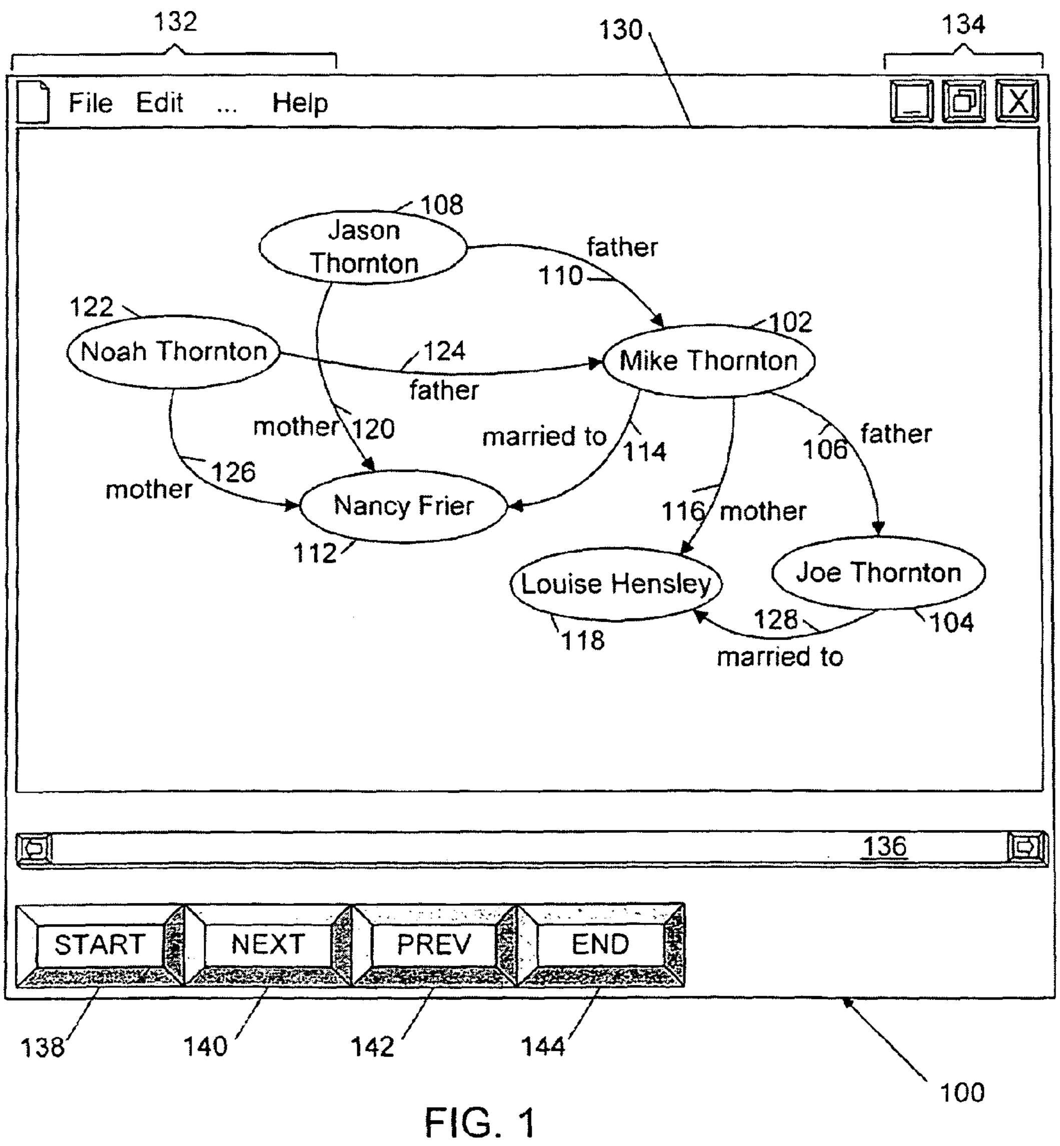

132
130
134
File Edit ... Help
108
Jason Thornton
father
110
122
Noah Thornton
124
102
Mike Thornton
father
mother
120
married to
114
106
father
mother
126
Nancy Frier
116
mother
112
Louise Hensley
Joe Thornton
128
104
118
married to
136
START
NEXT
PREV
END
138
140
142
144
100

FIG. 1

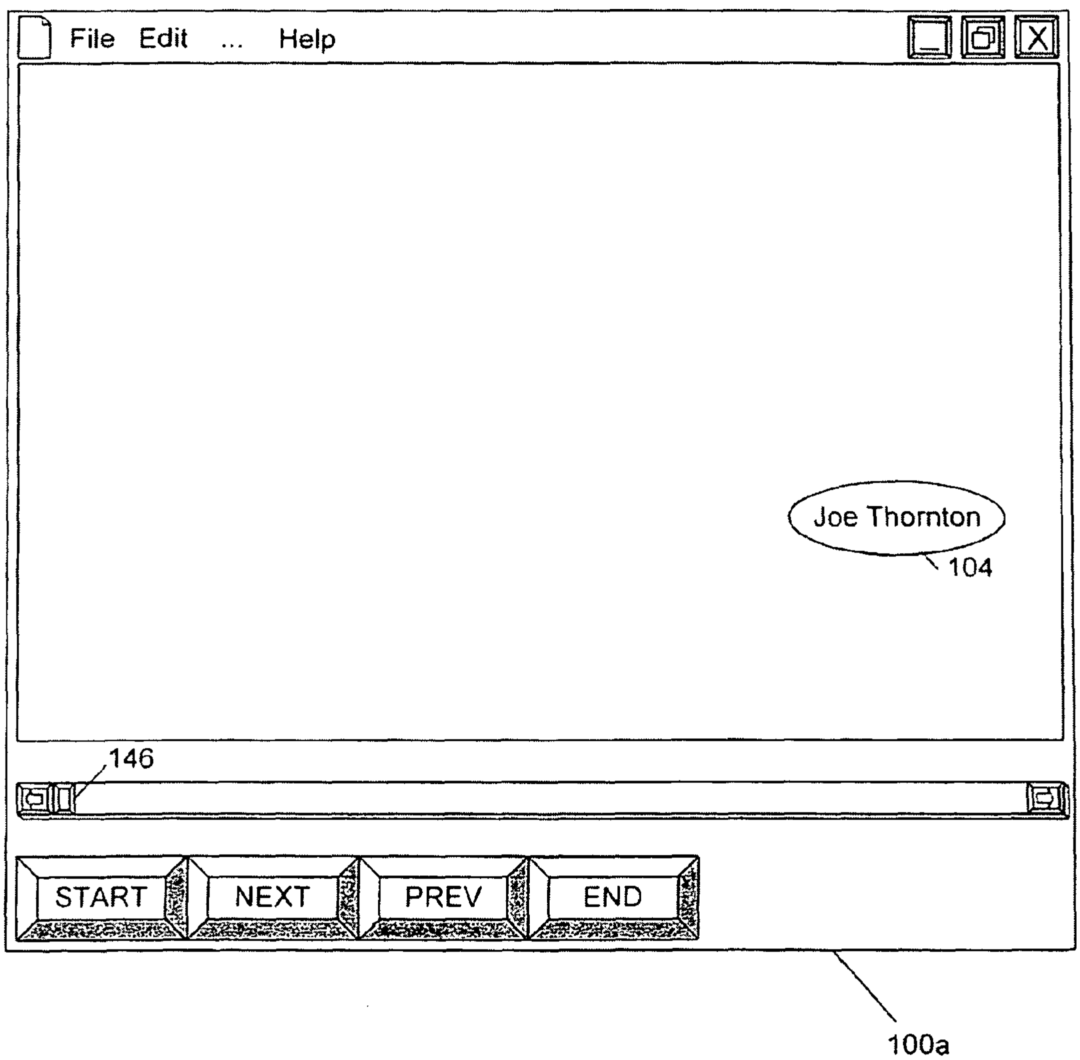


FIG. 2A

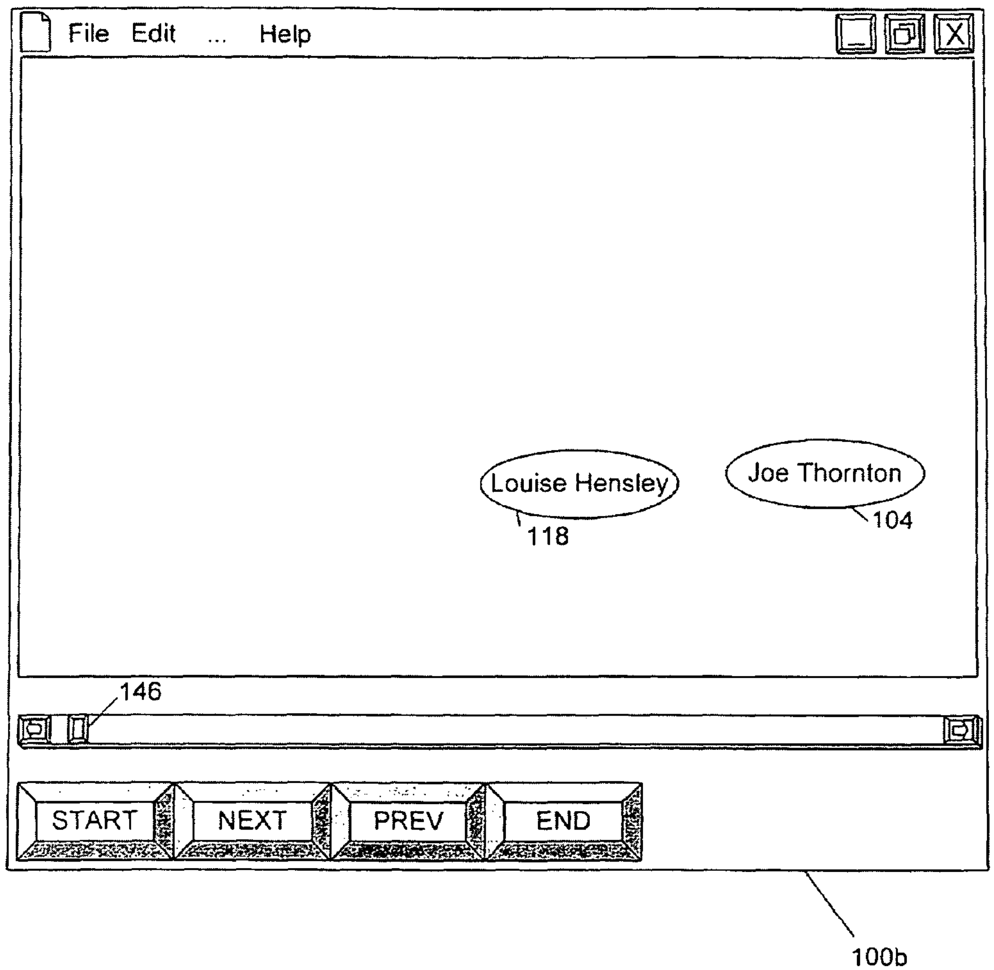

File Edit ... Help
Louise Hensley
118
Joe Thornton
104
146
START
NEXT
PREV
END
100b

FIG. 2B

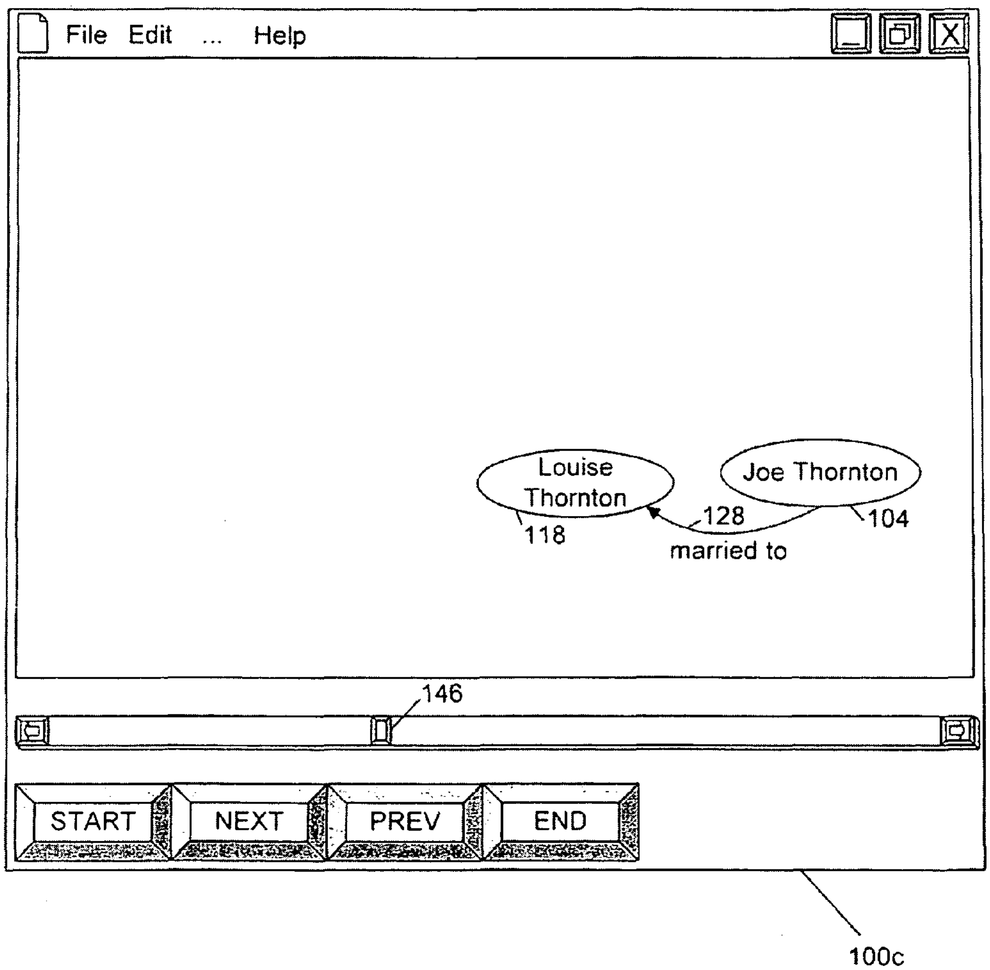

File Edit ... Help
Louise Thornton
Joe Thornton
118
128
104
married to
146
START
NEXT
PREV
END
100c

FIG. 2C

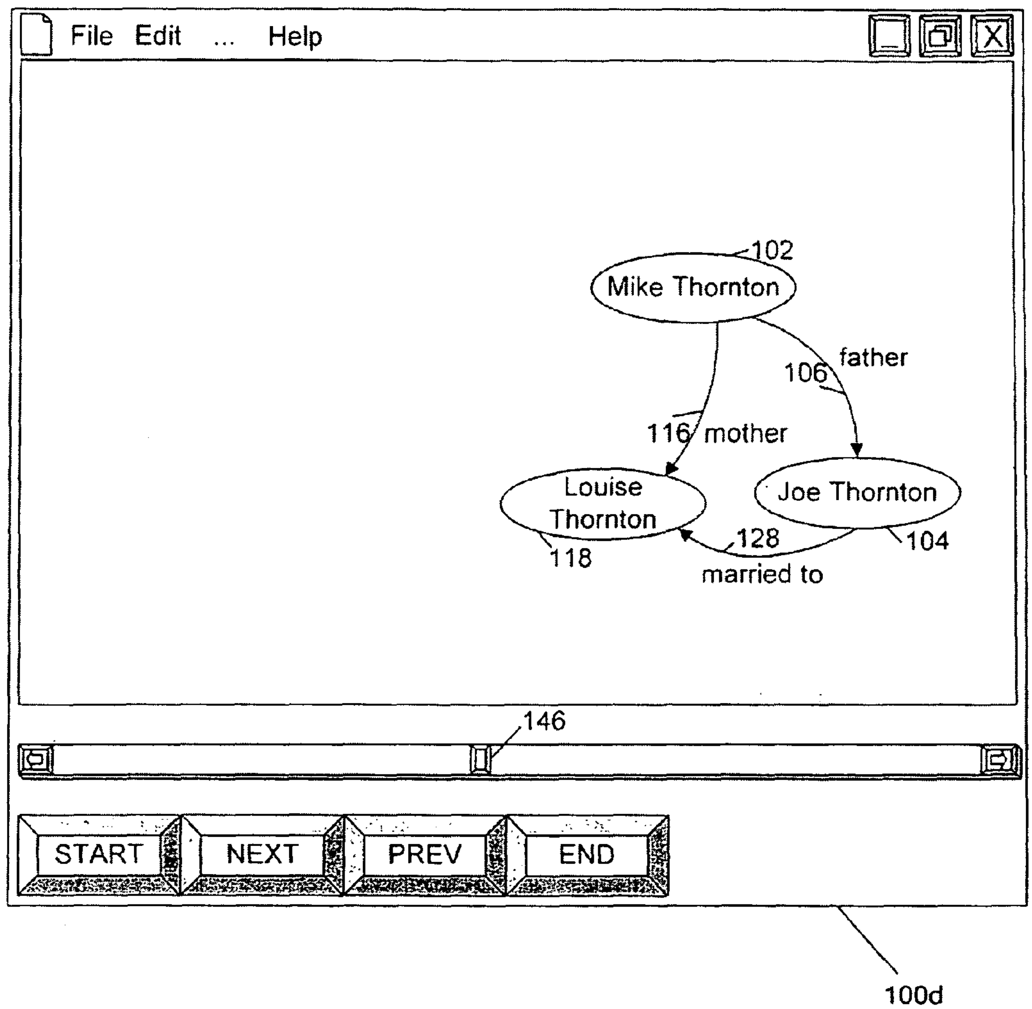

File Edit ... Help
102
Mike Thornton
father
106
116
mother
Louise Thornton
Joe Thornton
118
128
104
married to
146
START
NEXT
PREV
END
100d

FIG. 2D

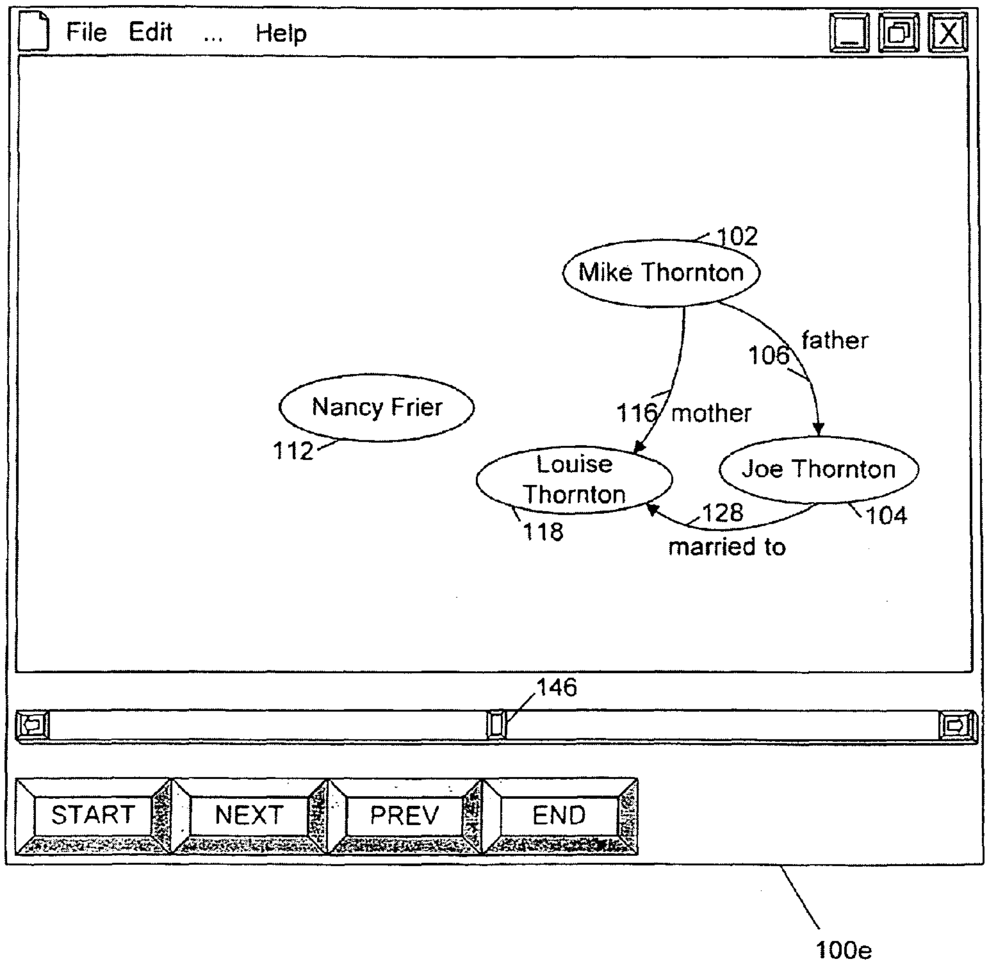
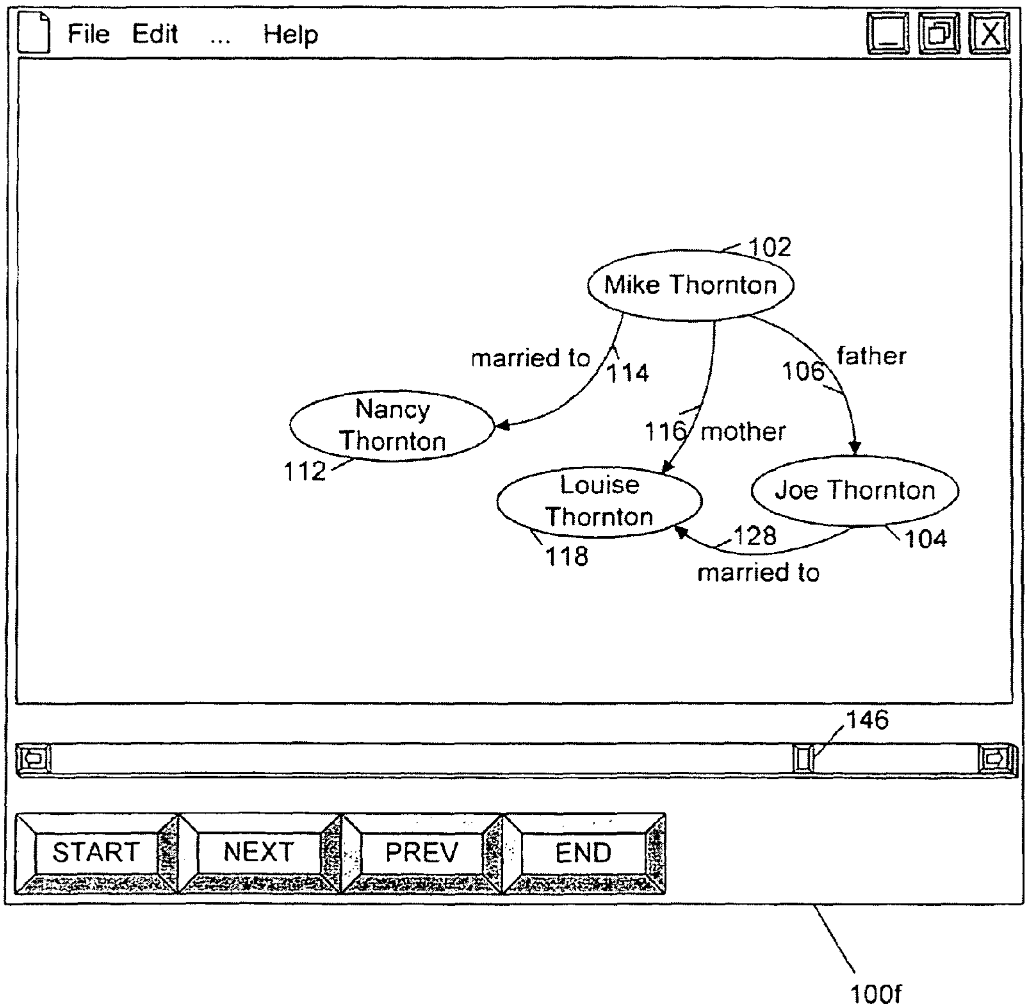
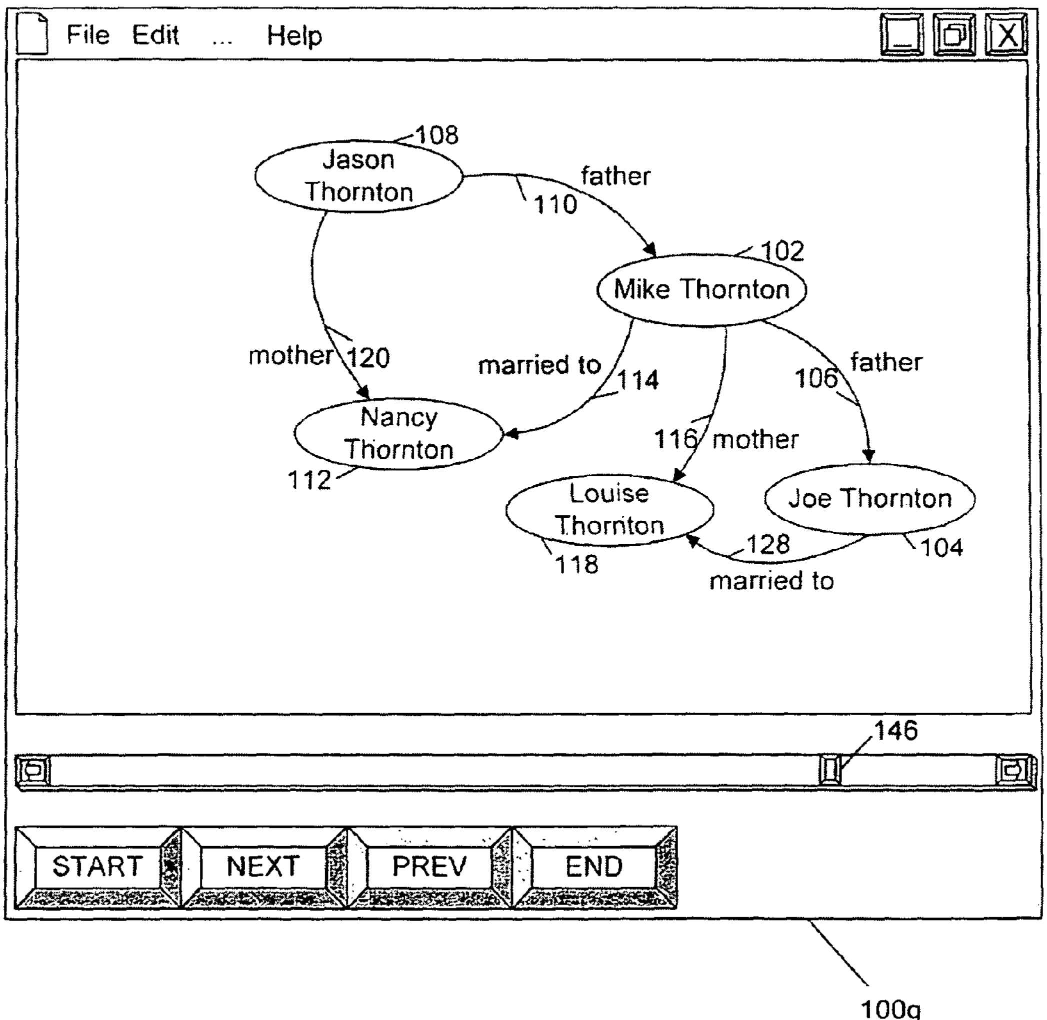

File Edit ... Help
102
Mike Thornton
father
106
Nancy Frier
116
mother
112
Louise Thornton
Joe Thornton
128
104
118
married to
146
START
NEXT
PREV
END
100e

FIG. 2E



File Edit ... Help
102
Mike Thornton
married to
114
106
father
Nancy Thornton
116
mother
112
Louise Thornton
Joe Thornton
118
128
104
married to
146
START
NEXT
PREV
END
100f

FIG. 2F



File Edit ... Help
108
Jason Thornton
father
110
102
Mike Thornton
mother
120
married to
114
106
father
Nancy Thornton
112
116
mother
Louise Thornton
Joe Thornton
118
128
104
married to
146
START
NEXT
PREV
END
100g

FIG. 2G

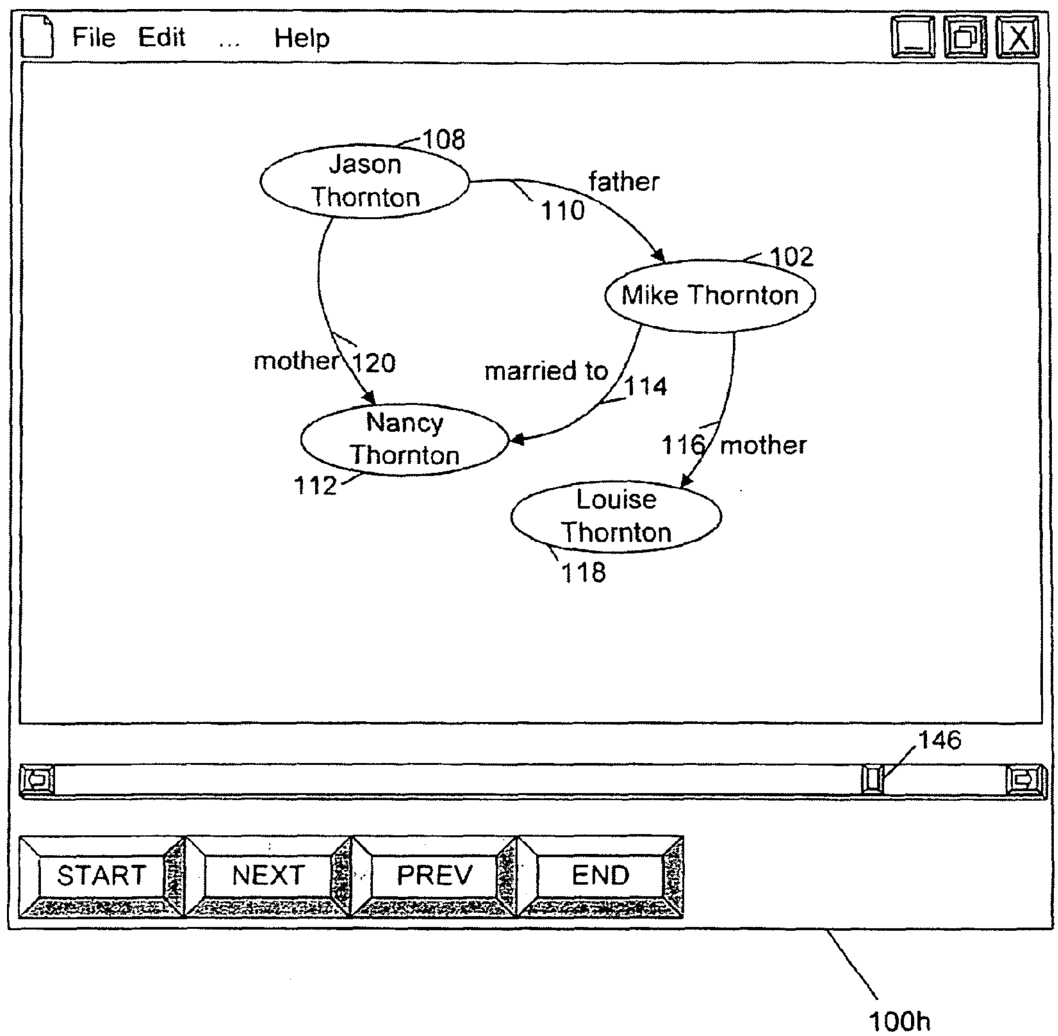

File Edit ... Help
108
Jason Thornton
father
110
102
Mike Thornton
mother
120
married to
114
Nancy Thornton
112
116
mother
Louise Thornton
118
146
START
NEXT
PREV
END
100h

FIG. 2H

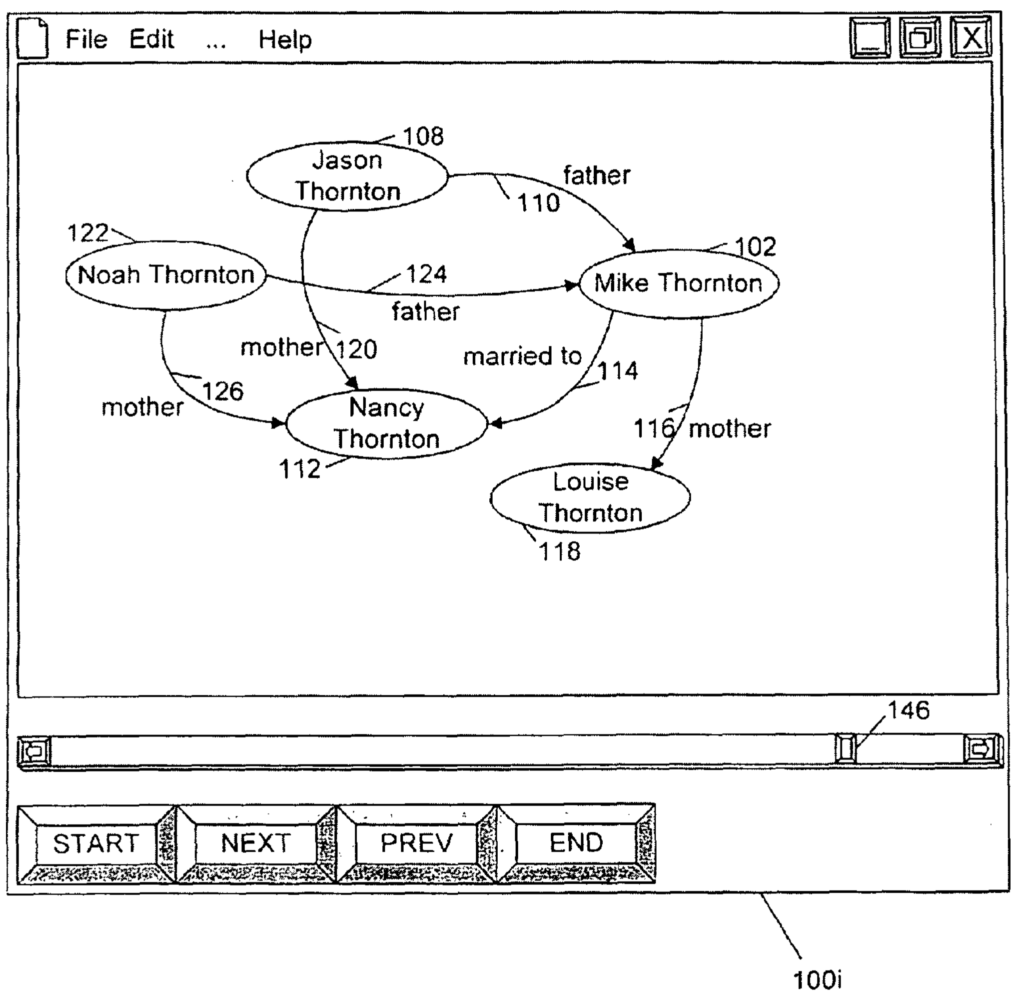

File Edit ... Help
108
Jason Thornton
father
110
122
Noah Thornton
124
Mike Thornton
102
father
mother
120
married to
114
126
mother
Nancy Thornton
116
mother
112
Louise Thornton
118
146
START
NEXT
PREV
END
100i

FIG. 2I

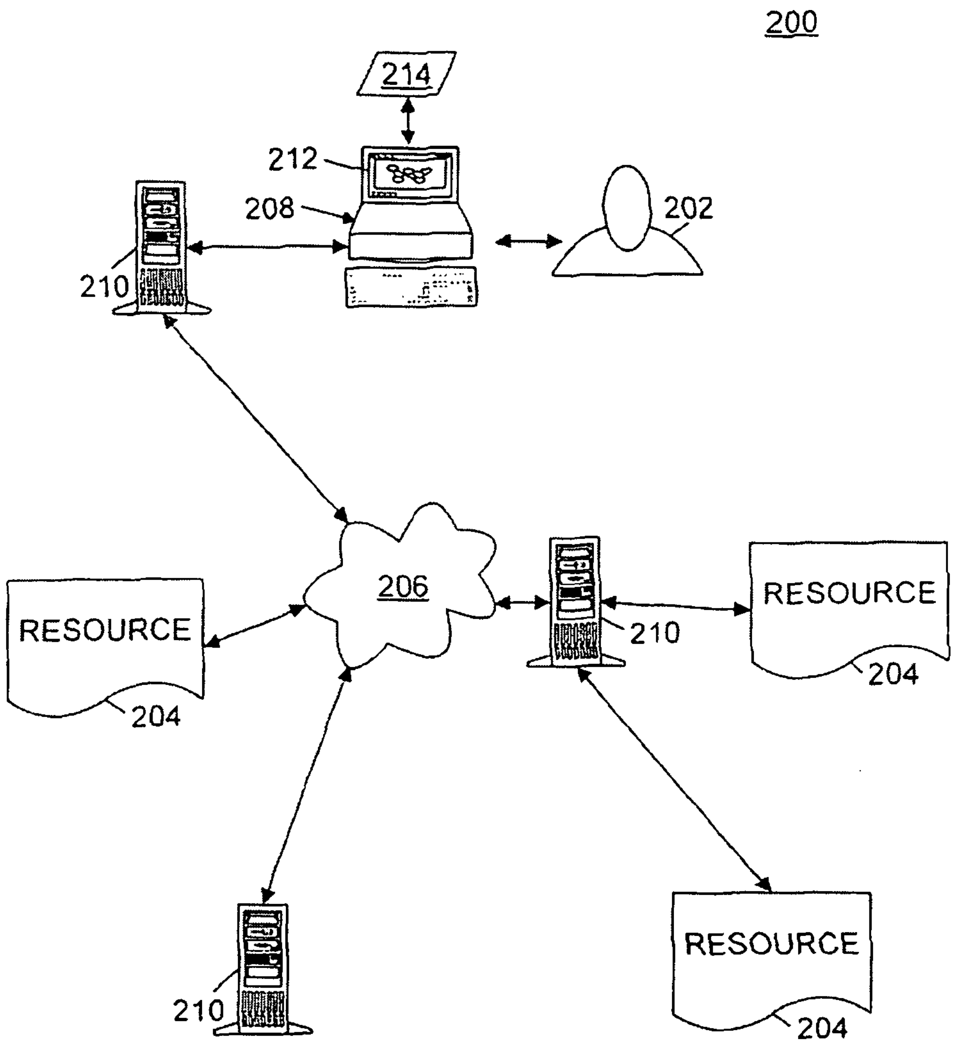

200
214
212
208
202
210
206
RESOURCE
204
210
RESOURCE
204
210
RESOURCE
204

FIG. 3

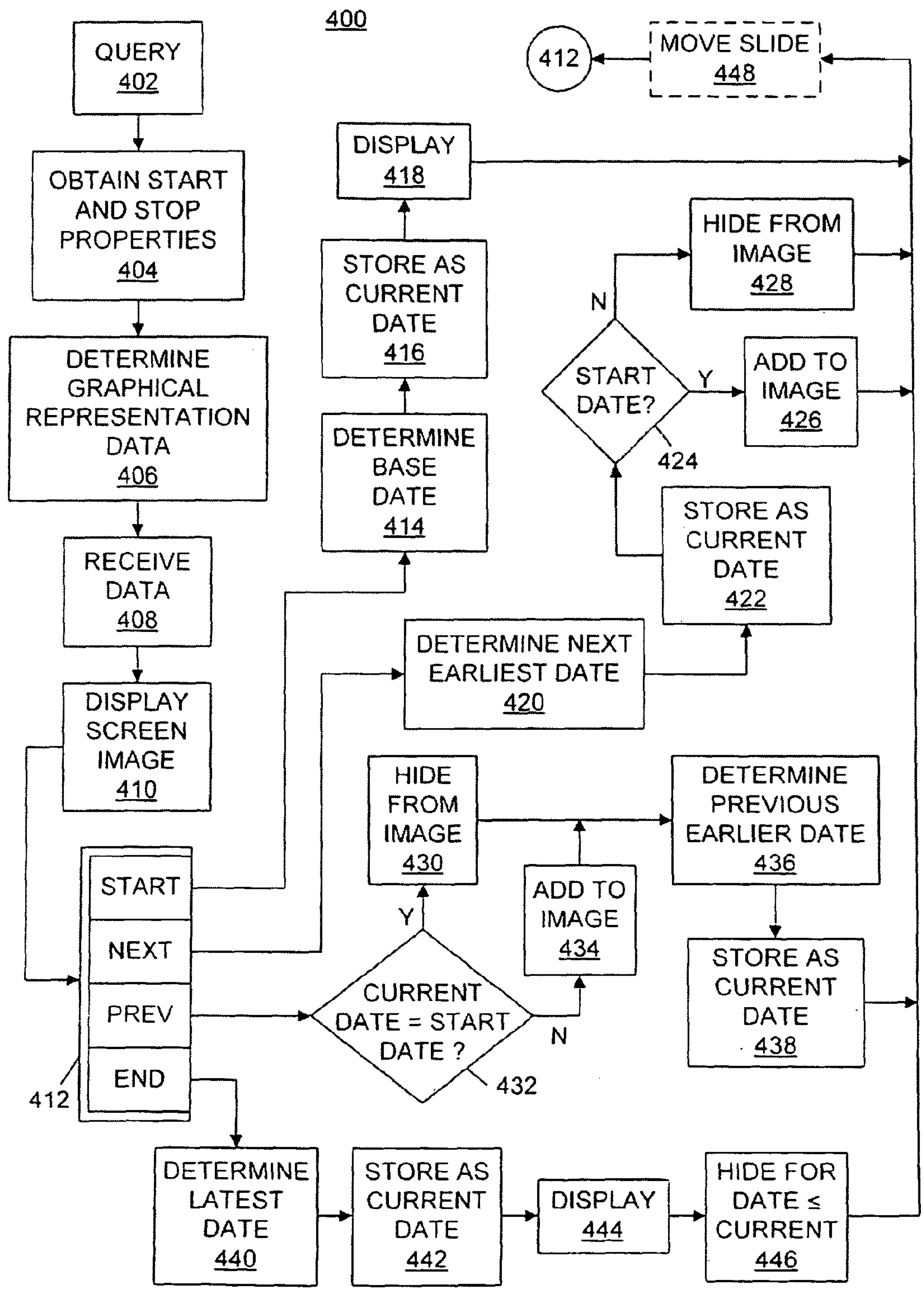

400
QUERY 402
OBTAIN START AND STOP PROPERTIES 404
DETERMINE GRAPHICAL REPRESENTATION DATA 406
RECEIVE DATA 408
DISPLAY SCREEN IMAGE 410
START
NEXT
PREV
END
412
DETERMINE BASE DATE 414
STORE AS CURRENT DATE 416
DISPLAY 418
DETERMINE NEXT EARLIEST DATE 420
STORE AS CURRENT DATE 422
START DATE?
424
N
Y
HIDE FROM IMAGE 428
ADD TO IMAGE 426
412
MOVE SLIDE 448
CURRENT DATE = START DATE ?
432
Y
N
HIDE FROM IMAGE 430
ADD TO IMAGE 434
DETERMINE PREVIOUS EARLIER DATE 436
STORE AS CURRENT DATE 438
DETERMINE LATEST DATE 440
STORE AS CURRENT DATE 442
DISPLAY 444
HIDE FOR DATE ≤ CURRENT 446

FIG. 4

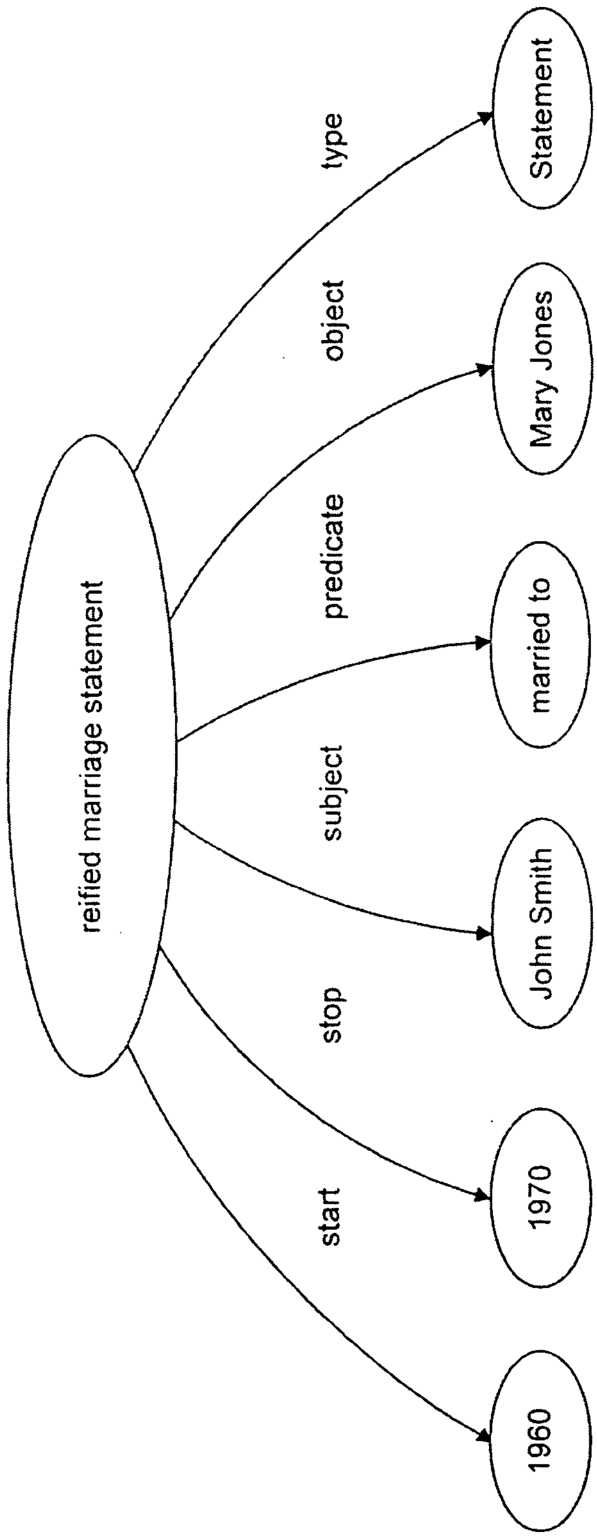

reified marriage statement
type
object
predicate
subject
stop
start
Statement
Mary Jones
married to
John Smith
1970
1960

FIG. 5A

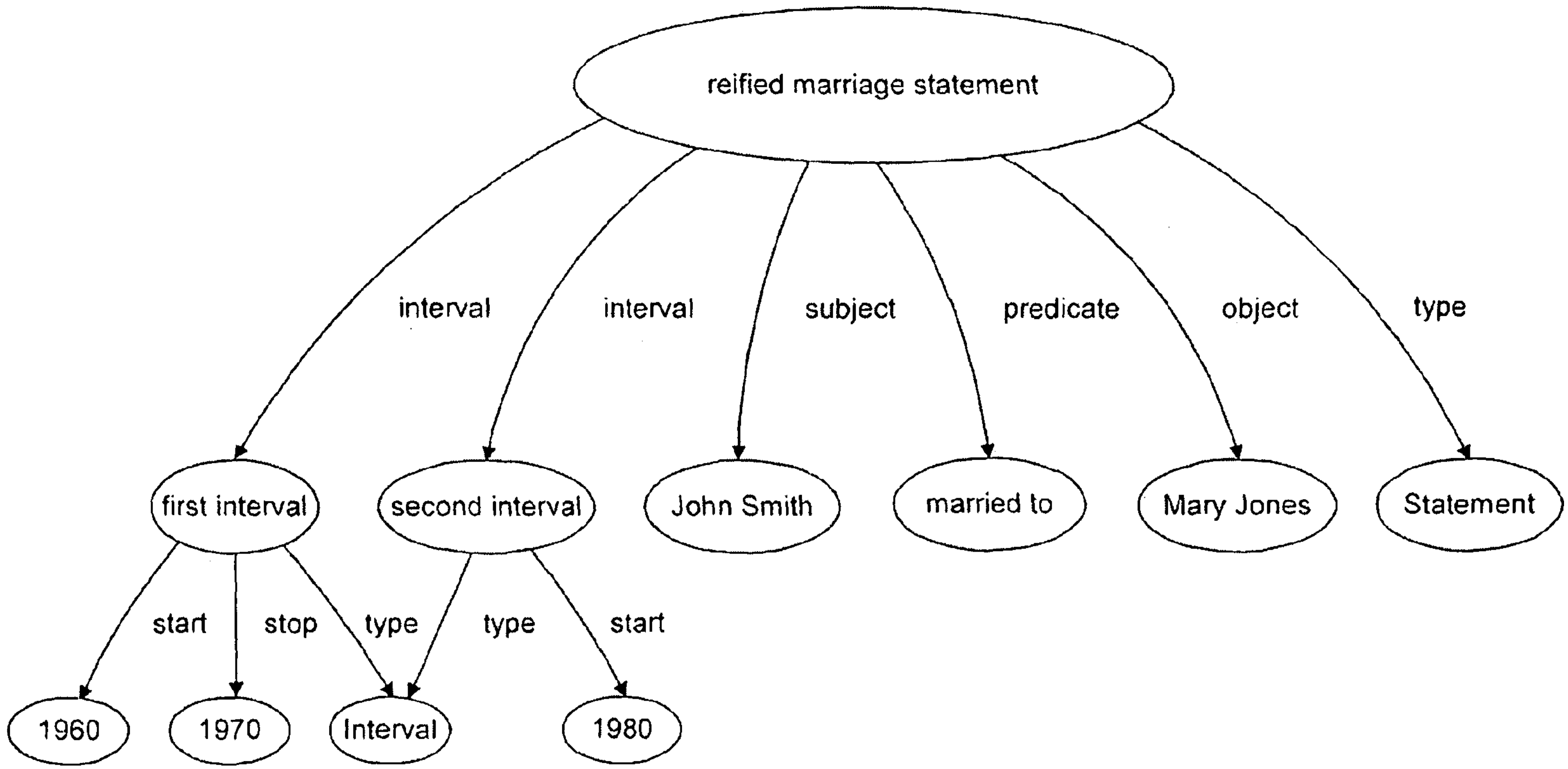

reified marriage statement
interval
interval
subject
predicate
object
type
first interval
second interval
John Smith
married to
Mary Jones
Statement
start
stop
type
type
start
1960
1970
Interval
1980

FIG. 5B

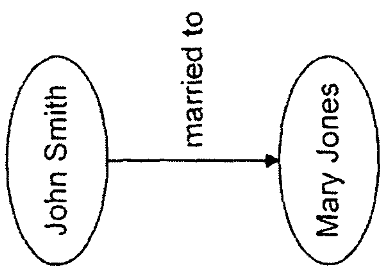


FIG. 5C

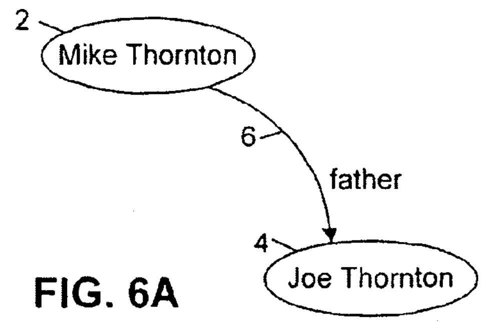


FIG. 6A
(PRIOR ART)

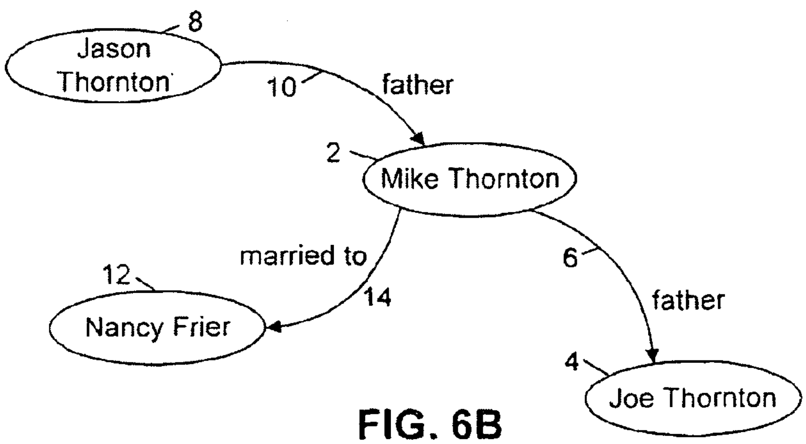


FIG. 6B
(PRIOR ART)

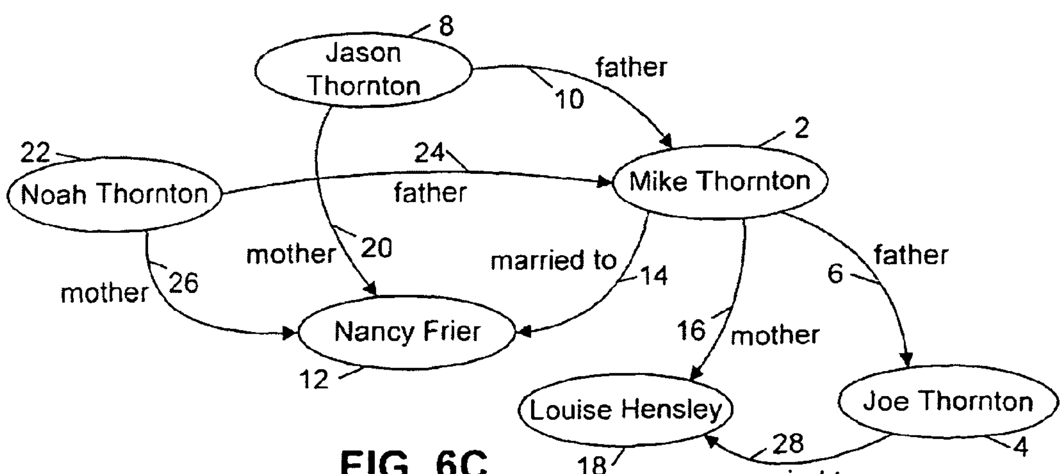


FIG. 6C
(PRIOR ART)

METHODS AND SYSTEMS FOR REPRESENTING, USING AND DISPLAYING TIME-VARYING INFORMATION ON THE SEMANTIC WEB

RELATED APPLICATIONS

This application is a continuation of copending, commonly assigned U.S. patent application Ser. No. 10/806,406, filed on Mar. 23, 2004, which claims priority to U.S. Provisional Patent Application No. 60/465,925, filed on Apr. 28, 2003. Both of these applications are incorporated by reference herein in their entirety. This application is co-pending with a related patent application entitled "Methods and Apparatus for Focusing Search Results on the Semantic Web" Ser. No. 10/803,551, by the same inventor and having assignee in common, filed concurrently herewith and incorporated by reference herein in its entirety.

GOVERNMENT INTEREST

The United States Government has a paid-up license in this invention and the right in limited circumstances to require the patent owner to license to others on reasonable terms as provided for by the terms of Contract No. F30602-00-C-0178 awarded by the Defense Advanced Research Projects Agency.

FIELD

The methods and systems relate to representing, using and displaying information, and more particularly to methods and systems for representing, using and displaying time-varying information on the Semantic Web.

BACKGROUND

The Semantic Web is an evolving collection of software tools and content, which provides information on the Internet, or World Wide Web, in such a way that it can be readily used by intelligent agents and other computer programs. Information on the Semantic Web, rather than being in natural language text, can be maintained in a structure workable by both computers and people. The Resource Description Framework (RDF) from the World Wide Web Consortium (W3C) underlies most Semantic Web efforts. RDF consists of statements (subject-predicate-object triples) made about instances of specific classes (similar to an object-oriented programming language).

The Resource Description Framework (RDF) is a general framework for how to describe an Internet resource such as a Web site and its content. An Internet resource is defined herein as a resource with a Uniform Resource Identifier (URI), including the Uniform Resource Locators (URLs) that identify Web sites as well as specific Web pages. Resources can also be physical objects (such as people) represented on Web pages. As with known HyperText Markup Language (HTML) META tags, the RDF description statements, encased as part of an Extensible Markup Language (XML) section, can be included within a Web page (HTML file), or can be in separate files.

RDF description statements can be represented as graphs containing nodes (instances or string literals) and arcs (statements). FIG. **6**A provides an example of such a graph for an RDF statement of the form, "Mike Thornton has a father Joe Thornton." For this RDF statement, "Mike Thornton" is the subject, "father" is the predicate, and "Joe Thornton" is the object. In the exemplary diagram, or graph of FIG. **6**A, the ovals can illustrate nodes representing resources (ovals **2** and **4**), and arcs can represent the named property, as shown by arc **6**. The direction of the arc can be from subject (**2**) to object (**4**). It can be understood that other representations besides the illustrated ovals and directional arcs can be used.

FIG. **6**B illustrates a graph of a collection of statements in which "Mike Thornton" (using an abbreviated form to represent a full URI) can be both the subject and object of various ones of the statements, including, "Jason Thornton has a father Mike Thornton," and "Mike Thornton is married to Nancy Frier." The subject "Jason Thornton" is represented by oval **8** and predicate "father" is represented by arc **10** from subject "Jason Thornton" (oval **8**) to object "Mike Thornton" (oval **2**). The object "Nancy Frier" is represented by oval **12** and predicate "married to" is represented by arc **14** from subject "Mike. Thornton" (oval **2**) to object "Nancy Frier" (oval **12**).

While such graphs as illustrated in FIGS. **6**A and **6**B can pictorially present the properties of subjects and objects, they can do so in a static fashion. For example, FIG. **6**C can illustrate an extended graph for statements concerning "Mike Thornton" taken from a genealogical resource. In addition to the statements in FIG. **6**R, FIG. **6**C can include the statements shown in Table 1.

Statement	Subject (Identifier)	Predicate (Identifier)	Object (Identifier)
Mike Thornton has a mother Louise Hensley	Mike Thornton (2)	mother (16)	Louise Hensley (18)
Noah Thornton has a father Mike Thornton	Noah Thornton (22)	father (24)	Mike Thornton (2)
Jason Thornton has a mother Nancy Frier	Jason Thornton (8)	mother (20)	Nancy Frier (12)
Noah Thornton has a mother Nancy Frier	Noah Thornton (22)	mother (26)	Nancy Frier (12)
Joe Thornton is married to Louise Hensley	Joe Thornton (4)	married to (28)	Louise Hensley (18)

It can be seen that Mike Thornton is neither the subject nor object of the last three statements in Table 1. However, these statements can be included in the graphical representation as having both subjects and objects in common with statements concerning "Mike Thornton."

Without additional statements providing dates for such events as births, deaths, or marriages, a user cannot determine time varying information from the graphs of FIGS. **6**A-C. For example, one cannot assess whether Noah is older or younger than Jason, or the relative ages of other individuals shown. Other time varying information, such as multiple marriages, can also present difficulties for the representations of FIGS. **6**A-C. Methods and systems are needed for determining and

graphically representing such information from Semantic Web structured resources to a user.

SUMMARY

The methods and systems described herein can include providing start and stop time properties to Semantic Web structured resources and statements. The start and stop time properties can specify a lifetime during which a resource or statement can be valid. A call or query to one or more resources can return statement data including the start and stop properties for the subjects and objects of the statements, and/or the statements themselves. Dates can be specified with the call or query such that the returned statements have lifetimes that include the specified dates. The specified dates can be used by a filter after obtaining the data for the query. Screen images of the data can display subject and object nodes and predicate arcs for the statement data. A sequence of screen images can display a timeline of nodes and arcs by adding or hiding nodes and arcs to correspond with the start and stop properties of the statements and nodes. Tools can be provided for the user to navigate through the sequence.

In one embodiment, a method of displaying Semantic Web statements having start properties and stop properties related to lifetimes of the statements includes displaying subjects and objects of the statements as nodes, displaying predicates of the statements as arcs connecting the nodes and labeled by the predicates, and hiding the nodes and arcs for subjects, objects, and statements having lifetimes outside of a timeframe selected by a user. Hiding can comprise painting the nodes and arcs of those statements to match a background of the display. One aspect of the embodiment includes providing tools by which the user can select the timeframe. The user can be given options to select a start timeframe corresponding to an earliest one of the start properties of the statements, to select an end timeframe corresponding to a latest one of the start properties of the statements, and/or to select a timeframe increment for displaying the statements in temporal order corresponding to the start properties and the stop properties of the statements. Nodes can be labeled with their URI's or with the value of a literal property, such as a name, which may itself vary over time based on the start and stop time properties of statements using that property.

In one embodiment, a system for displaying graphical representations of time varying information for Semantic Web structured statements includes a processor connected to Semantic Web structured resources and receiving input from a user, including a query to retrieve selected statements matching the query. Application program interfaces (APIs) determine the selected statements from the resource and obtain the start and stop properties for subjects and objects of the matching statements and for the statements themselves. The APIs also determine graphical representation data from the selected statements and their properties. The processor receives the graphical representation data and control a display to present the graphical representations of the selected statements. The processor controls the display to hide graphical representations of those statements whose lifetime does not include a timeframe input by the user. The system include an application tool set operable by the user to input the timeframe, wherein the user can select timeframe increments corresponding to the start and stop properties of the selected statements.

In one embodiment, a method of displaying graphical representations of time varying information for Semantic Web structured statements from Semantic Web resources includes receiving a query to retrieve selected statements that match a query, determining the selected statements from the Semantic Web structured resources, obtaining start and stop properties for subjects and objects of the selected statements and for the statements themselves, determining graphical representation data for the selected statements and the properties, filtering the graphical representation data to control a display to present graphical representations of the statements, and controlling the display to hide the graphical representations of those statements whose lifetimes exclude a selected timeframe.

In one embodiment, a computer-readable medium includes instructions for controlling a processor to associate a lifetime with a Semantic Web structured statement by implementing a start property for the statement that denotes a start time when the statement becomes valid, and implementing a stop property for the statement that denotes a stop time when the statement ceases to be valid, wherein the lifetime of the statement is denoted by a time interval between the start time and the stop time. The start property and the stop property can be implemented as an XML Schema Datatype, including an xsd:dateTime datatype, an xsd:date datatype and/or a xsd:gYear datatype.

The instructions include instructions for controlling a processor to display a plurality of statements on a display by displaying subjects and objects of the statements as nodes, displaying predicates of the statements as arcs connecting the nodes, and hiding nodes and arcs for particular statements when a selected display timeframe is outside the lifetimes of those particular statements. The instructions include instructions for controlling a processor to hide the nodes and arcs by painting the nodes and arcs for those particular statements to match a background of the display.

The instructions include instructions for controlling a processor to display a toolset operable by a user to select said timeframe. The toolset can be operable by the user to select a start timeframe corresponding to an earliest one of said start properties of said statements, to select an end timeframe corresponding to a latest one of said stop properties of said statements, and/or to select timeframe increments for displaying the statements in temporal order corresponding to their start properties and stop properties.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings, which are incorporated in and constitute a part of this specification, illustrate several embodiments of the invention and together with the description, serve to explain the principles of the invention.

FIG. **1** illustrates a screen image of a graphical representation of statements taken from a Semantic Web resource;

FIGS. **2**A-**2**I illustrate time varying graphical representations of the statements of FIG. **1**;

FIG. **3** illustrates a system for providing time varying graphical representations of statements from a Semantic Web resource;

FIG. **4** illustrates allow chart of a method of implementing time varying graphical representations of statements from a Semantic Web resource;

FIG. **5**A illustrates a statement associated directly with start and stop properties; and

FIG. **5**B illustrates a statement having multiple Interval instances.

FIG. **5**C illustrates a reified version of a statement.

FIGS. **6**A-**6**C illustrate prior art graphical representations of statements from Semantic Web structured resources;

DETAILED DESCRIPTION

To provide an overall understanding, certain illustrative embodiments will now be described; however, it will be

understood by one of ordinary skill in the art that the systems and methods described herein can be adapted and modified to provide systems and methods for other suitable applications and that other additions and modifications can be made without departing from the scope of the systems and methods described herein.

Unless otherwise specified, the illustrated embodiments can be understood as providing exemplary features of varying detail of certain embodiments, and therefore, unless otherwise specified, features, components, modules, and/or aspects of the illustrations can be otherwise combined, separated, interchanged, and/or rearranged without departing from the disclosed systems or methods. Additionally, the shapes and sizes of components are also exemplary and unless otherwise specified, can be altered without affecting the disclosed systems or methods.

FIG. **1** shows a screen image of a graphical representation of RDF statements from a Semantic Web resource. For simplicity, the graphical representation of FIG. **1** can include the statements from the genealogical resource as in FIG. **6**C. The elements in FIG. **1** having numbering offset by 100 from those of FIG. **6**C refer to corresponding elements of the statements described with respect to FIG. **6**C. It can be understood that the numbering of elements in FIG. **1** and other figures described further herein, is shown for ease in describing the features of the graphical representations and need not be viewable by a user.

In addition to the subject, predicate and object for each statement, the RDF statements and Semantic Web resources for use with the methods and systems described herein can have associated start and stop properties. The time interval starting with a specified start time and before a specified stop time can be referred to as the lifetime of the statement or resource. Closed lifetimes include lifetimes having both start and stop times specified. Open-ended lifetimes include those having one of the start or stop times specified. Infinite lifetimes include those having neither a start or stop time specified.

The Resource Description Framework (RDF) from the World Wide Web Consortium (W3C) can underlie most Semantic Web efforts. While implementation of the start and stop properties can include various known protocols or datatypes for providing and communicating such properties among resources and applications, the use of standardized protocols, properties, and datatypes can be preferred so as to provide for wide use of the methods and systems described herein. Thus, in one embodiment, the start and stop properties can make use of the xsd:dateTime datatype from the W3C XML Schema Datatypes Recommendation, though other datatypes, e.g., xsd:date orxsd:gYear, can be used.

If multiple time intervals are associated with a given statement or resource (instance), e.g., a marriage relation between two people who divorce and then remarry each other, then instances of the class Interval can be used to group start/stop intervals. Thus, rather than having start and stop properties associated directly with the object or statement, the statement can have multiple Interval instances, which each can have its own start and stop properties.

FIG. **5**A illustrates an example of statement **502** (a reified version of statement is shown in FIG. **5**C) having start property **504** and stop property **506** directly associated with statement **502**. FIG. **5**B illustrates the example of FIG. **5**A, wherein statement **502** has multiple instances **508**, **510** of the class Interval **512**. Instance **508**, with respective start and stop properties **504** and **506**, corresponds with the interval for statement **502** of FIG. **5**A, while instance **510** shows the addition to statement **502** of a second interval with start property **514**. For the marriage relation example discussed above, the first interval **508** of the marriage can indicate the marriage (statement **502**) began in 1960 (start property **504**) and ended in 1970 (stop property **506**). The second interval **510** can indicate that the same marriage, i.e., marriage between the same two people, began again in 1980 (start property **514**). Intervals can be associated with instances as well as with statements.

In addition to its start and stop properties, the lifetime of a statement can also be constrained by the lifetimes of resources that it can reference as a subject or object. For example, a marriage relation ends when one of the participants dies.

Start and stop properties will typically be associated with statements by using RDF statementIDs. The use of RDF statementIDs can result in both asserted and reified statements. The technique can be equally applied to content involving only reified statements. When applied to such content, the graph structure for each reified statement can be constructed explicitly without the use of statement IDs.

The screen images of FIGS. **1** and **2**A-I can be described with relation to the systems **200** and method **400** of FIGS. **3** and **4**, respectively. FIG. **3** illustrates an exemplary system **200** for presenting time-varying information to a user **202** from one or more Semantic Web structured resources **204**. User **202** can connect to network **206** via processor **208**. One or more servers **210** can facilitate connections to network **206** by user **202** and resources **204**, though it can be understood that processor **208** and/or resources **204** can be configured for direct connection to network **206**. Processor **208** can include a display **212** by which screen images, such as screen image **100** of FIG. **1** and the screen images of FIGS. **2**A-I can be viewed by the user **202**.

FIG. **4** is a flow chart for a method **400** of implementing time varying graphical representations of statements from a semantic web resource. User **202** of FIG. **3** can query (**402**) one or more Semantic Web structured resources, such as resources **204** of FIG. **3**, using. Application Program Interfaces (APIs) **214**. As previously described with respect to FIGS. **6**A-C, APIs for Semantic Web languages can include models containing sets of RDF Statements, as well as graphical representations linking resources and statements. In addition, the APIs **214** of FIG. **3** for the systems and methods described herein can include obtaining the start and stop properties for the statements and resources selected by the user **202** and using the start and stop properties in displaying time varying graphical representation to user **202**. While the APIs **214** are shown in FIG. **3** as directly accessible, or as part of processor **208**, it can be understood that servers **210** and/or resources **204** can include APIs **214**, or that APIs **214** can be distributed among one or more servers **210**; and/or resources **204**.

Table 2 shows exemplary stop and start properties for the subjects, objects, and statements of FIG. **1**.

TABLE 2

Statement	Subject (Identifier) Start Stop	Predicate (Identifier)	Object (Identifier) Start Stop	Start	Stop
1. Mike Thornton has a father Joe Thornton	Mike Thornton (102) May 29, 1957 —	father (106)	Joe Thornton (104) Mar. 16, 1928 Jun. 14, 1992	May 29, 1957	Jun. 14, 1992
2. Jason Thornton has a father Mike Thornton	Jason Thornton (108) Aug. 05, 1987 —	father (110) —	Mike Thornton (102) May 29, 1957 —	Aug. 05, 1987	—
3. Mike Thornton is married to Nancy Frier	Mike Thornton (102) May 29, 1957 —	married to (114)	Nancy Frier (112) Aug. 19, 1958 —	Nov. 02, 1982	—
4. Mike Thorton has a mother Louise Thornton	Mike Thornton (102) May 29, 1957 —	mother (116)	Louise Hensley (118) Nov. 04, 1929 —	May 29, 1957	—
5. Noah Thornton has a father Mike Thornton	Noah Thornton (122) Feb. 15, 1994 —	father (124)	Mike Thornton (102) May 29, 1957 —	Feb. 15, 1994	—
6. Jason Thornton has a mother Nancy Frier	Jason Thornton (108) Aug. 05, 1987 —	mother (120)	Nancy Frier (112) Aug. 19, 1958 —	Aug. 05, 1987	—
7. Noah Thornton has a mother Nancy Frier	Noah Thornton (122) Feb. 15, 1994 —	mother (126)	Nancy Frier (112) Aug. 19, 1958 —	Feb. 15, 1994	—
8. Joe Thornton is married to Louise Hensley	Joe Thornton (104) Mar. 16, 1928 Jun. 14, 1992	married to (128)	Louise Hensley (118) Nov. 04, 1929 —	Sep. 17, 1955	Jun. 14, 1992

As indicated in Table 2, start and stop properties can be associated with the subjects and objects of the statements, as well as the statements themselves. For example, the subject (Mike Thornton) of statement 1 of Table 2 has a start date of 05/29/57, indicating Mike Thornton's birth date, and an open stop date, indicating Mike Thornton is living. The statement with predicate father has a start date corresponding to Mike Thornton's birth date and a stop date of 06/14/92, indicating the father relationship with Joe Thornton ends on that date. By looking at the object (Joe Thornton) stop date, it can be seen that 06/14/92 corresponds to Joe Thornton's death, the reason for the stop date for the statement.

In one embodiment consistent with the invention, start and start properties can be associated with the statements and resources. Continuing with the example of statement 1 of Table 2, in this embodiment statement 1 can have a start property of 5/29/57, corresponding to the date Mike Thornton was born, and a stop property of 06/14/92. Without further information, the stop property can refer to a number of events by which the father relationship of Mike and Joe Thornton can end, including Mike's or Joe's death. In this embodiment, start and stop properties associated with subjects and objects can be used to obtain start and stop properties for the related statements as listed in Table 2. For example, the statements "Joe Thornton has a birth event of Mar. 16, 1928" "Joe Thornton has a death event of 06/14/92" can be used to determine the start and stop properties for Joe Thornton. The absence of a statement for a death event for Mike Thornton can indicate Mike Thornton has an open stop property. The above can illustrate that the lifetime of a statement can be further restrained by the lifetimes of its subject and object.

Referring again to FIG. **4**, APIs **214** of FIG. **3**, in response to the user **202** query, can obtain (**404**) the statements with start and stop properties from resources **204** matching the user **202** query, including the start and stop properties for the statements, as shown in Table 2, and can determine (**406**) the corresponding data for the graphical representations. Processor **208** of FIG. **3** can receive (**408**) the data and display (**410**) the corresponding screen image, such as image **100** of FIG. **1**. Screen image **100** includes a view **130** in which the graphical representation can be displayed. Screen image **100** includes one or more file and view manipulation tools, such as pull down menus **132**, action buttons **134** and scroll bar **136**.

In addition to such known items or tools, screen image **100** includes time varying activation buttons, including START button **138**, NEXT button **140**, PREV (previous) button **142** and END button **144**. It can be understood that varying means for implementing the functions or actions to be described with relation to the activation buttons can be used, including pull down menus, icons, keyboard entries, etc., and that the activation buttons shown in FIG. **1** are for illustrative purposes and are not restrictive as to the type, style and/or design of means user **202** can employ for displaying the time varying data provided by APIs **214**. In the exemplary embodiment of FIG. **4**, the choice of an activation button by user **202** is illustrated at **412**.

When user **202** chooses start button **138**, method **400** determines the earliest or base start property date (**414**), stores the date as the current active date (**416**) and displays (**418**) the corresponding subjects, objects and/or statements. For the earliest property, the display can include the one subject or object corresponding to the earliest start property. In one

embodiment, displaying the corresponding subject or object at **418** includes hiding subjects, objects and statements not to be displayed as by painting those subjects, objects, or statements in the background color of the screen image. For the exemplary statements of Table 2, the earliest start date (03/16/28) corresponds with Joe Thornton (**104**). FIG. **2**A illustrates the corresponding screen image **100***a*, wherein the subjects, objects, and statements besides Joe Thornton (**104**) are hidden.

When the NEXT button **140** is chosen, method **400** determines the next earliest start or stop property date (**420**) based on the stored current active date and again the method **400** stores the date determined as the current active date (**422**). If a start property is the next earliest date, as determined at **424**, the display of the corresponding subjects, objects and/or predicates is added (**426**) to the screen image. When **424** determines that a stop property is the next earliest date, the display of the corresponding subjects, objects and/or predicates is hidden (**428**) from the screen image.

FIGS. **2**B-I illustrates selection of the NEXT button **140** from FIG. **2**A. For FIG. **2**B, the next earliest date (11/04/29) corresponds to a start property for Louise Hensley. Thus, Louise Hensley (**18**) can be added to the screen image. FIGS. **2**C-G correspond to the start property dates for statement 8 ("Joe Thornton married to (**28**) Louise Hensley") (9/17/55), Mike Thornton (5/29/57), Nancy Frier (08/19/58), statement 3 ("Mike Thornton married to (**14**) Nancy Frier") (11/08/82), and Jason Thornton (08/05/87), respectively. In one embodiment, illustrated with particularity in FIGS. **2**C and **2**F, it can be seen that the "married to" predicate can also correspond to a change of the name property used to label the nodes for Louise Hensley and Nancy Frier, respectively. Such name changes can be reflected in the statements returned by APIs **214**. For example, Table 2 includes additional statements 3a, 3b, 8a and 8b associated with statements 3 and 8, respectively, as indicated below in Table 2A.

TABLE 2A

Statement	Subject (Identifier) Start Stop	Predicate (Identifier)	Object (Literal)	Start	Stop
3a. Person has a name "Nancy Frier"	Person Aug. 19, 1958 —	name	"Nancy Frier"	Aug. 19, 1958	Nov. 08, 1982
3b. Person has a name "Nancy Thornton"	Person Aug. 19, 1958 —	name	"Nancy Thornton"	Nov. 02, 1982	
8a. Person has a name "Louise Hensley"	Person Nov. 04, 1929 —	name	"Louise Hensley"	Nov. 04, 1929	Sep. 15, 1955-
b. Person has a name "Louise Thornton"	Person Nov. 04, 1929 —	name	"Louise Thornton"	Sep. 17, 1955	

Continuing with the selection of NEXT from FIG. **2**G, the next earliest date corresponds to a stop property for Joe Thornton (06/14/92). Thus, in FIG. **2**H, Joe Thornton (**4**) and the associated predicates "father" (**6**) and "married to" (**28**) are hidden. The selection of NEXT from FIG. **2**H determines that the next earliest date corresponds to start date (02/15/94) for Noah Thornton (**22**). Thus, in FIG. **2**I Noah Thornton (**22**) is added, as well as predicates "father" (**24**) and "mother" (**26**).

When the PREV button **142** is chosen, the method **400** can hide (**430**) corresponding subjects, objects, and/or statements for the current active date when the current active date is a start property date, as determined at **432**. When the current active date is a stop property date, the method **400** adds (**434**) the corresponding subjects, objects, and/or statements for the current active date. The method **400** determines (**436**) and stores the previous earlier date as the current active date (**438**). It can be seen that selection of the PREV button **142** reverses the process described in relation with selection of the NEXT button **140** and the sequence of screen images **100***b-i* of FIGS. **2**B-I.

When the END button **144** is chosen, the method **400** determines (**440**) the latest property date and store the latest date as the current date (**442**). Method **400** can displays (**444**) the subjects, predicates and objects for the statements and hide (**446**) those subjects, objects, and statements having stop properties equal to or less than the determined current date. FIG. **2**I illustrates the resulting screen image **100***i* when the user **202** chooses the END button **144** for the exemplary data of Table 2 and Table 2A. In the embodiment of FIG. **4**, the flow chart for method **400** indicates that after displaying the appropriate screen image (as at **418**, **426**, **428**, **438** and **446**) method **400** can return to **412** to await further button activations by user **202**. User **202** can end the display or return to perform new queries using the file or view manipulation tools, such as pull down menus **132**.

In addition to displaying time varying information as described above, the use of start and stop properties for the statements and resources can be used to filter the statements returned by APIs **214**. In this embodiment, user **202** can specify a date, or range of dates with the query at **402**. APIs **214** can obtain the start and stop properties (**404**) and return the graphical representation data (**406**) for those statements having a lifetime that includes the date(s) specified. For example, user **202** can specify the current date. Based on Table 2 and Table 2A, the lifetimes of statements 2-7, 3a, 3b, 8a and 8b include the current date, and those statements will be returned by APIs **214**. Thus, it can be seen that the screen image for the specified date can include screen image **100***i* of FIG. **2**I.

For a specified range of dates, the APIs **214** can return statements having lifetimes that overlap the specified range of dates. For example, user **202** can specify dates in the range of 01/01/50 to 01/01/90. Again using Table 2 and Table 2A, the lifetimes of statements 1-4, 6, 8, 3a, 3b, 8a and 8b can include the specified range and it can be seen that the screen image for the specified range can include screen image **100***g* of FIG. **2**G. While APIs **214** can typically return statements including the current date, the current date can be adjusted to provide for date ranges, without having to re-fetch the data.

In one embodiment, scroll bar **136** of FIG. **1** can represent a timeline corresponding to the time from the earliest start property date of the returned statements to the latest stop

property date of the returned statements. For the exemplary statements of Table 2 and Table 2A, the scroll bar can represent a timeline from the birth of Joe Thornton (03/16/28) to the current date. Slide **146**, illustrated in FIGS. **2**A-I, can be positioned on scroll bar **136** and can correspond to selecting a date for the screen image to be presented. Slide **146** can be activated when user **202** chooses one of the buttons **138-144**, as indicated in phantom at **448** in FIG. **4**. Thus, slide **146** can be inactive or hidden in screen image **100** of FIG. **1**. For example, FIG. **2**F illustrates slide **146** positioned at 01/01/85, thus screen image **100***f* can include statements having lifetimes that include the date 01/01/85.

The systems and methods described herein may not be limited to a particular hardware or software configuration. The techniques described herein can be implemented in hardware or software, or a combination thereof. The systems and methods can be implemented in one or more computer programs executing on one or more programmable computers, such as may be exemplified by processor **208**, servers **210**, or APIs **214**, among others, that include a processor, a storage medium readable by the processor (including volatile and non-volatile memory and/or storage elements), one or more input devices, and one or more output devices.

The computer programs, or programs, may be preferably implemented using one or more high level procedural or object-oriented programming languages to communicate with a computer system; however, the program(s) can be implemented in assembly or machine language, if desired. The language can be compiled or interpreted. The computer program(s) can be preferably stored on a storage medium or device (e.g., CD-ROM, hard disk, or magnetic disk) readable by a general or special purpose programmable computer for configuring and operating the computer when the storage medium or device is read by the computer to perform the procedures described herein. The system can also be considered to be implemented as a computer-readable storage medium, configured with a computer program, where the storage medium so configured causes a computer to operate in a specific and predefined manner.

As provided herein, the processor(s) can thus be embedded in one or more devices that can be operated independently or together in a networked environment, where the network can include, for example, a Local Area Network (LAN), wide area network (WAN), and/or can include an intranet and/or the Internet and/or another network. The network(s) can be wired or wireless or a combination thereof and can use one or more communications protocols to facilitate communications between the different processors. The processors can be configured for distributed processing and can utilize, in some embodiments, a client-server model as needed. Accordingly, the methods and systems can utilize multiple processors and/or processor devices, and the processor instructions can be divided amongst such single or multiple processor/devices.

The device(s) or computer systems that integrate with the processor(s) can include, for example, a personal computer(s), workstation (e.g., Sun, HP), personal digital assistant (PDA), handheld device such as cellular telephone, laptop, handheld, or another device capable of being integrated with a processor(s) that can operate as provided herein. Accordingly, the devices provided herein are not exhaustive and are provided for illustration and not limitation.

References to "a microprocessor" and "a processor", or "the microprocessor" and "the processor," can be understood to include one or more microprocessors that can communicate in a stand-alone and/or a distributed environment(s), and can thus can be configured to communicate via wired or wireless communications with other processors, where such one or more processor can be configured to operate on one or more processor-controlled devices that can be similar or different devices. Furthermore, references to memory, unless otherwise specified, can include one or more processor-readable and accessible memory elements and/or components that can be internal to the processor-controlled device, external to the processor-controlled device, and can be accessed via a wired or wireless network using a variety of communications protocols, and unless otherwise specified, can be arranged to include a combination of external and internal memory devices, where such memory can be contiguous and/or partitioned based on the application. Accordingly, references to a database can be understood to include one or more memory associations, where such references can include commercially available database products (e.g., SQL, Informix, Oracle) and also proprietary databases, and may also include other structures for associating memory such as links, queues, graphs, trees, with such structures provided for illustration and not limitation.

References to a network, unless provided otherwise, can include one or more intranets and/or the Internet. References herein to microprocessor instructions or microprocessor-executable instructions, in accordance with the above, can be understood to include programmable hardware.

While the method and systems have been disclosed in connection with the preferred embodiments shown and described in detail, various modifications and improvements thereon will become readily apparent to those skilled in the art. As an example, those with ordinary skill in the art will recognize that the arrangement and connectivity of the components shown in the figures are merely for illustrative purposes, and can be varied accordingly and components may be combined or otherwise reconfigured without departing from the scope of the disclosed systems and methods. Accordingly, many additional changes in the details and arrangement of parts, herein described and illustrated, can be made by those skilled in the art. It will thus be understood that the following claims are not to be limited to the embodiments disclosed herein, can include practices otherwise than specifically described, and are to be interpreted as broadly as allowed under the law.

What is claimed is:

1. A computer-implemented method of using Resource Description Framework (RDF) reification to associate Semantic Web statements with start properties and stop properties related to lifetimes of the Semantic Web statements using a reification processor, comprising:

accessing an RDF statement from a Semantic Web resource wherein the RDF statement includes a subject, a predicate, and an object;

determining a lifetime of the subject of the RDF statement, wherein determining the lifetime of the subject is based on at least one of a start property of the subject and a stop property of the subject;

determining a lifetime of the predicate of the RDF statement, wherein determining the lifetime of the predicate is based on at least one of a start property of the predicate and a stop property the predicate;

determining a lifetime of the object of the RDF statement, wherein determining the lifetime of the object is based on at least one of a start property of the object and a stop property of the object;

automatically determining a lifetime of the RDF statement based on an overlap of the lifetime of the subject, the lifetime of the predicate, and the lifetime of the object;

generating a reified RDF statement, using the reification processor, wherein the reified RDF statement includes the subject, the predicate, the object and the lifetime of the RDF statement; and

storing the reified RDF statement in the Semantic Web resource.

2. The method of claim **1**, further comprising:

receiving a Semantic Web query having an associated timeframe;

determining if the query timeframe is within the lifetime of a reified RDF statement in the Semantic Web resource; and

accessing the reified RDF statement in response to the determination.

3. The method of claim **1**, further comprising:

displaying on a display the subject and the object of the reified RDF statement as nodes;

displaying on the display the predicate of the reified RDF statement as an arc connecting the displayed nodes;

selecting a timeframe associated with the display; and

hiding the nodes and the arc when the selected display timeframe is outside the lifetime of the reified RDF statement.

4. The method of claim **1**,

wherein automatically determining the lifetime of the RDF statement comprises selecting the lifetime of the subject of the RDF statement as the lifetime of the RDF statement.

5. The method of claim **1**,

wherein automatically determining the lifetime of the RDF statement comprises selecting the lifetime of the object of the RDF statement as the lifetime of the RDF statement.

6. The method of claim **1**, wherein determining the lifetime of the RDF statement comprises:

comparing the lifetime of the object and the lifetime of the subject; and

in response to the comparison, selecting an intersection of the compared lifetimes as the lifetime of the RDF statement.

7. The method of claim **1**,

wherein automatically determining the lifetime of the RDF statement comprises selecting the lifetime of the predicate of the RDF statement as the lifetime of the RDF statement.

8. The method of claim **1**, wherein the lifetime of the RDF statement includes at least one of an open-ended start property and an open-ended stop property.

9. The method of claim **1**, wherein the lifetime of the RDF statement is explicitly specified.

10. The method of claim **1**, wherein the RDF statement is accessed from a Semantic Web resource and further comprising storing the reified RDF statement in the Semantic Web resource.

11. The method of claim **1**, wherein the lifetime of at least one of the subject, object, and predicate includes at least one of an open-ended start property and an open-ended stop property.

12. The method of claim **1**, wherein automatically determining a lifetime of the RDF statement further comprises determining the lifetime of the RDF statement based on at least one of a start and a stop property associated with the RDF statement.

13. A system for using Resource Description Framework (RDF) reification to associate Semantic Web statements with start properties and stop properties related to lifetimes of the Semantic Web statements, comprising:

a computer processor operable to

access an RDF statement from a Semantic Web resource, wherein the RDF statement includes a subject, a predicate, and an object,

determine a lifetime of the subject of the RDF statement, wherein determining the lifetime of the subject is based on at least one of a start property of the subject and a stop property of the subject,

determine a lifetime of the predicate of the RDF statement, wherein determining the lifetime of the predicate is based on at least one of a start property of the predicate and a stop property of the predicate,

determine a lifetime of the object of the RDF statement, wherein determining the lifetime of the object is based on at least one of a start property of the object and a stop property of the object, and

determine a lifetime of the RDF statement based on an overlap of the lifetime of the subject, the lifetime of the predicate, and the lifetime of the object; and

a reification processor operable to

generate a reified RDF statement, wherein the reified RDF statement includes the subject, the predicate, the object and the lifetime of the RDF statement; and

store the reified RDF statement in the Semantic Web resource.

14. The system of claim **13**, wherein the computer processor is further operable to:

receive a Semantic Web query having an associated timeframe;

determine if the query timeframe is within the lifetime of a reified RDF statement in the Semantic Web resource; and

access the reified RDF statement in response to the determination.

15. The system of claim **13**, further comprising a display operable to:

display the subject and the object of the reified RDF statement as nodes;

display the predicate of the reified RDF statement as an arc connecting the displayed nodes;

select a timeframe associated with the display; and

hide the nodes and the arc when the selected display timeframe is outside the lifetime of the reified RDF statement.

16. A non-transitory computer-readable medium comprising instructions for controlling a processor to use Resource Description Framework (RDF) reification to associate Semantic Web statements with start properties and stop properties related to lifetimes of the Semantic Web statements by:

accessing an RDF statement from a Semantic Web resource wherein the RDF statement includes a subject, a predicate, and an object;

determining a lifetime of the subject of the RDF statement, wherein determining the lifetime of the subject is based on at least one of a start property of the subject and a stop property of the subject;

determining a lifetime of the predicate of the RDF statement, wherein determining the lifetime of the predicate is based on at least one of a start property of the predicate and a stop property the predicate;

determining a lifetime of the object of the RDF statement, wherein determining the lifetime of the object is based on at least one of a start property of the object and a stop property of the object;

automatically determining a lifetime of the RDF statement based on an overlap of the lifetime of the subject, the lifetime of the predicate, and the lifetime of the object;

generating a reified RDF statement, using a reification processor, wherein the reified RDF statement includes the subject, the predicate, the object and the lifetime of the RDF statement; and

storing the reified RDF statement in the Semantic Web resource.

17. The non-transitory computer-readable medium of claim **16** further comprising instructions for controlling the processor to:

receive a Semantic Web query having an associated timeframe;

determine if the query timeframe is within the lifetime of a reified RDF statement in the Semantic Web resource; and

access the reified RDF statement in response to the determination.

18. The non-transitory computer-readable medium of claim **16** further comprising instructions for controlling the processor to:

display on a display the subject and the object of the reified RDF statement as nodes;

display on the display the predicate of the reified RDF statement as an arc connecting the displayed nodes;

select a timeframe associated with the display; and

hide the nodes and the arc when the selected display timeframe is outside the lifetime of the reified RDF statement.

19. The non-transitory computer-readable medium of claim **16**,

wherein automatically determining the lifetime of the RDF statement comprises selecting the lifetime of the subject of the RDF statement as the lifetime of the RDF statement.

20. The non-transitory computer-readable medium of claim **16**,

wherein automatically determining the lifetime of the RDF statement comprises selecting the lifetime of the object of the RDF statement as the lifetime of the RDF statement.

21. The non-transitory computer-readable medium of claim **16** further comprising instructions for controlling the processor to:

compare the lifetime of the object and the lifetime of the subject; and

in response to the comparison, select an intersection of the compared lifetimes as the lifetime of the RDF statement.

22. The non-transitory computer-readable medium of claim **16**,

wherein automatically determining the lifetime of the RDF statement comprises selecting the lifetime of the predicate of the RDF statement as the lifetime of the RDF statement.

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